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**On**

**Selection of Power Systems for Aids to Navigation and Associated Equipment**

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International Association of Marine Aids to Navigation and Lighthouse Authorities

Document Revisions

Revisions to the IALA Document are to be noted in the table prior to the issue of a revised document.

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**Selection of Power Systems for Aids to Navigation and Associated Equipment**

# Introduction

The purpose of this Guideline is to assist Authorities in the selection and design of power systems for Aids to Navigation (AtoN).

This guideline contains descriptions of power generation, energy storage, load identification and calculation methodologies that are available for use with AtoN, together with their advantages and disadvantages.

Suggestions on Life Cycle Management issues are also addressed in the document.

# How to use this guideline

This document is an overarching guideline and needs to be read in conjunction with the following documents:

IALA Guideline No. 1067-1 on Total Electric Loads of Aids to Navigation

IALA Guideline No. 1067-2 on Power Sources

IALA Guideline No. 1067-3 on Electrical Energy Storage for Aids to Navigation

## Scope

This guideline is focused on delivery of power systems for AtoN but may equally be applied to ancillary services such as security systems, remote control, monitoring and domestic loads.

The following flowchart shows the steps needed to make the best use of this guideline.

## Application of the 1067 Guideline



1. Flowchart for Application of the 1067 Guideline

# Selection of Power Systems and Energy Storage

This section identifies those items that should be taken into consideration when selecting energy storage and associated power systems for AtoN locations. Table 1 provides general guidance on the most appropriate power systems for a number of locations, power requirements and environmental issues. However, it would be prudent to use the appropriate guideline to better determine the potential and define the optimal solution.

## General

The power requirement for AtoN cannot be based on the light source in isolation because the power system provides for the total needs of the AtoN. This may include fog signals, lights, RACONs, remote control and monitoring facilities, security and domestic loads. Domestic loads can vary substantially - demand on manned stations will be at a constant high level, while the demand on unmanned stations would only occur during maintenance visits.

In addition to the development of new light sources, the automation of lighthouses and systems and changing user requirements play a significant part in the relevance and size of power supplies.

However, developments in technology have made it possible to reduce the power consumption of AtoN without any detrimental effect on the service provided to mariners. In particular, battery systems, rather than diesel generators, can be used as back up for utility power or as the companion of renewable energy sources. Integrated power system lanterns may also meet the requirements, thus eliminating the need for external power generation and energy storage.

## Guidance on Power Sources

Where power is supplied by others, reliable and readily available, this may be the cheapest energy source. When utility power is used, it is sufficient to provide back-up facilities by means of energy storage solutions. The capacity of the device need only be sufficient to enable time for access to site and repair.

Where externally supplied power is difficult or impossible to install, solar energy, wind energy or other renewable source of energy should be considered as the next option. In some situations where renewable energy source is not practicable, primary batteries can be used.

Diesel generators should only be considered for major loads.

Table 1 provides information on the practical choice of energy storage systems and guidance on the application of power sources for aids to navigation.

1. Selection Guide of power systems for AtoN

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Power Systems** | **Remote Site** | **No Easy Access** | **High Power > 300 Wh / day** | **Medium Power 300 – 100 Wh / day** | **Low Power**  **< 100 Wh / day** | **Extreme Temperatures** | **Ventilation not possible** | **Buoy** | **Major Floating Aid** | **Life Expectancy (estimated years)** |
| **Utility power** | +o | + | ++ | ++ | + | ++ | ++ | - | - | - |
| **Diesel generator** | + | o | + | - | - | o | o | - | - | 20 |
| **Solar** | ++ | ++ | - | + | ++ | ++ | - | ++ | ++ | 20 |
| **Wind HAWG\*** | ++ | - | + | ++ | ++ | o | - | o | o | 1 to 15 |
| **Wind VAWG\*\*** | ++ | - | + | ++ | ++ | ++ | - | + | + | 10 to 50 |
| **Fuel Cell** | ++ | - | + | ++ | ++ | - | o | - | - | 15 |
| **Hybrid** | ++ | ++ | o | ++ | + | + | o | ++ | ++ | Not applied |
| *++*  *+*  *o* | *Recommended solution*  *Good solution*  *Not recommended* | | | +o | Recommended solution where utility power is available | | | |  |  |

\*HAWG: Horizontal Axis Wind Generator

\*\* VAWG: Vertical Axis Wind Generator

1. Selection Guide of energy storage equipment for AtoN

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Energy Storage** | **Remote Site** | **Maintenance Required** | **High Power**  **> 300**  **Wh / day** | **Medium Power**  **300 - 100**  **Wh / day** | **Low Power**  **< 100**  **Wh / day** | **Extreme Temperatures** | **Ventilation not possible** | **Buoy** | | **Major Floating Aid** | **Life Expectancy**  **(years)/cycles** |
| **Lead acid** | + | Yes | + | + | + | - | - | o | | + |  |
| **Sealed lead acid** | ++ | No | - | o | + | - | - | ++ | | + |  |
| **VRLA\*** | + | No | o | + | + | - | - | o | | - |  |
| **Pocket NiCd** | ++ | Yes\*\*\* | + | + | + | + | - | o | | + |  |
| **Sintered NiCd** | + | No | + | + | + | + | - | o | | + |  |
| **Sealed NiCd** | ++ | No | + | + | + | + | - | ++ | | + |  |
| **Air depolarized** | o | No | - | - | + | o | - | + | | o |  |
| **Alkaline** | o | No | - | - | + | o | ++ | + | | o |  |
| **Zinc-Carbon** | - | No | - | - | + | - | ++ | + | | - |  |
| **Ni-MetalHydride** | + | No | + | + | + | - | - | + | | + |  |
| **Lithium (secondary)\*\*** | + | No | + | + | + | - | - | + | | + |  |
| **Lithium (primary)** | + | No | o | o | + | + | ++ | + | | o |  |
| **Super Capacitor** | o | No | o | o | o | o | o | o | | o |  |
| *++* | *Recommended solution* | | |  |  | | | | |  |  |
| *+* | *Good solution* | |  | o | *Not recommended* | | | | - | No comment |  |

\* VRLA: Valve Regulated Lead Acid

\*\* Caution must be applied when specifying this battery type as the battery chemistry can vary widely thereby offering differing degrees of performance and safety requirements

\*\*\* Charge level dependant

## Redundancy and Autonomy

## User Requirements

The user requirement also has an important part to play in power consumption. For every mile reduction in range for lights the required luminous intensity is roughly halved and hence power consumption reduced. The application of visual and audible AtoNs is changing; ranges are being reduced considerably, resulting in far less power demand.

## Automation

Automation will reduce the need for constant domestic loads, but is very likely to require the use of control devices to ensure that navigation equipment operates when required. Typical examples are day/night sensing for the light sources, fog detectors for fog signals and state of charge sensors for diesel generators.

### Disadvantages

The continual reduction of power consumption and thus the requirement for smaller power supplies has distinct advantages, but when this is applied to buildings that were previously occupied, there are building conditioning issues that should be recognised and addressed. The result could be damp conditions leading to the deterioration of the building itself as well as the AtoN equipment.

Where mains power is available, heating or dehumidification can be provided without increasing the capacity of back up power supplies. However, with renewable energy or hybrid operated systems there is likely to be no spare capacity for building conditioning as this would negate any savings made.

In these cases alternatives need to be considered including:

* Improved ventilation;
* Good building maintenance;
* Ancillary powered heating either by high efficiency gas or diesel fired boilers, solar or wind generators;
* High efficiency Stirling cycle engine to provide heating as well as electrical power.

# Life Cycle Management Considerations

The Life Cycle Management covers from conception to disposal and is having an increasing impact on the design and selection of equipment and has also a direct link to the overall financial requirements.

## Initiation phase

### Capturing the Mariners Requirements

The start of any AtoN project is that a requirement is identified by a maritime entity. This could range from a vague idea to a thoroughly considered approach. When developing the design criteria for the final solution, it is imperative to achieve full and concise design requirements from the initiating body.

### Consideration of Design Options

Careful consideration should be given to the ‘Through Life Costs’ of any solution as a low capital cost solution could offer very high running costs and vice versa.

It is therefore important to consider the true overall cost of ‘Ownership’ of the AtoN. This consideration should take into account such issues as maintenance periods, equipment replacement periods and environmental implications, both through life and at end of life disposal therefore, end of life recycling / disposal costs should be considered.

It should also be noted that in some areas an acceptable solution may be to use lower-priced batteries and accept that their replacement may be necessary more frequently than for specialist batteries. Such a decision will be influenced by the cost of accessing the AtoN site, and by the ease of fast access in the event of a failure.

### Heritage

With certain AtoN refurbishment or replacement projects, heritage issue may become a consideration. The costs of replacing an ‘Artefact’ piece of equipment cannot be overlooked. These costs are not only monetary, but could be deemed to be a cost on history and could be ignored to the projects detriment. Consideration therefore should be given to the re-use in the new project or leaving the redundant equipment ‘In situ’ for others to see, or relocation of the artefact to a museum or similar place. In any case the cost of any solution should include this.

### Design life

To enable a final solution to be defined and agreed by the initiating entity a clear view should be available to them that encompasses all the initial criteria, or at least offers them options for consideration.

## Implementation and In-Service phases

During the in-service life of the AtoN equipment, it is important to monitor the performance of the equipment to ensure the protection of the environment. Appropriate measures should be taken to limit the impact of the maintenance activities on the environment.

Maintenance activities should be appropriate to protect the heritage status of the sites and be compliant with the current regulation, where applicable.

It is recommended that the maintenance requirements be evaluated during the conception phase in a manner to extend the maintenance interval wherever possible.

## Disposal phase

The disposal of any equipment has to be considered during the conception phase in order to minimize the impact on the environment.

Disposal of equipment containing hazardous materials is an increasingly important factor and the emphasis must be put on reworking/reusing components to extend life and then the re-cycling of equipment in preference to disposal. Disposal of non-reusable equipments or components should be limited to the minimum.

It is important to ensure that any disposal of AtoN equipment is done according to current regulations and limits the negative impact on the environment as much as possible.

Consideration should be given to passing on obsolete equipment to a museum, if it might be of interest to future generations.

# References

1. Solar Photovoltaic Glossary

Note that the terms relating to the solar photovoltaic part of the system are extracted from IEC TC 82 ‘Solar photovoltaic energy systems Guide: Glossary of terms and symbols used in solar photovoltaic energy systems - part I - 82/154’.

Attention is drawn to the IALA Dictionary, chapter 6, Power Supplies for Stations, Section 2 Natural Energy Sources and Low Level Sources. Also Section 4 Electrochemical Cells and Batteries.

Array:

A mechanically integrated assembly of modules or panels together with support structure but exclusive of foundation, tracking, thermal control and other such components, to form a DC power producing unit.

Autonomy of a Battery:

The autonomy of a battery is a theoretical concept. It indicates the time in days (or hours) a battery will take to discharge from a fully charged state [100 % state of charge (SOC)] to a chosen cut-off level state of charge, powering the AtoN system **without** any energy coming from the generator.

The cut-off level is chosen by the designer according to the battery technology used.

It should be noted that the electrical power consumed by the AtoN system (in Ah/day or Wh/day) may vary with weather conditions and/or season of the year. It is recommended to use the worst conditions (night duration & temperature) to calculate the battery autonomy.

100%

Cut-off level

0%

Time

Autonomy

1. Autonomy of a Battery

Conversion efficiency:

The ratio of maximum electrical power output to the product of photovoltaic device area and incident irradiance measured under defined test conditions and expressed as a percentage.

Current-voltage characteristics (I = f (V)):

The output current of a photovoltaic device as a function of output voltage at a particular temperature and irradiance.

Fill Factor (FF):

The ratio of maximum power to the product of open-circuit voltage and short-circuit current is



Irradiance:

(Wm־²) radiant power incident upon unit area of surface.

Irradiance, Direct (Wmֿ²):

The radiant power from the sun's disc and from a small circumsolar region of the sky within a subtended angle of 5º incident upon unit area.

Irradiance, Diffuse: (Wmֿ²):

The total radiant power incident upon a unit area excluding the direct irradiance.

Irradiation:

Integration of irradiance over a specified period of time (MJm־² per hour, day, week, month, year, as the case may be).

Module:

The smallest complete environmentally protected assembly of cells.

Module area:

The entire frontal area of the module, including borders and frame (m²).

Module packaging efficiency:

The ratio of the total cell area to module area.

Panel:

A group of modules fastened together, pre-assembled and wired, designed to serve as an installable unit in an array and/or sub-array.

Panel area (m²):

The entire frontal area of the panel, including modules, inter-module framework and spacing.

Panel packing efficiency:

The ratio of the total module area to panel area.

Photovoltaic effect:

Direct conversion of radiant energy into electrical energy.

Photovoltaic (PV) System:

An installed aggregate of components and subsystems that combine to use the photovoltaic effect to convert solar energy into electrical energy suitable for connection to an application load. In its simplest form a PV system consists of a PV array with connections to the load, but it may also include power conditioning, monitoring and control equipment, energy storage and power distribution units.

Rated current:

The measured value of current of a PV device at rated voltage under Specified Operating Conditions.

Rated maximum power:

The value of maximum power of a photovoltaic device under Specified Operating Conditions.

Rated power:

The value of power output of a photovoltaic device at rated voltage under Specified Operating Conditions.

Rated voltage:

The voltage at which a PV device is designed to produce near maximum electrical power under Specified Operating Conditions.

Reference solar cell:

A solar cell used to measure irradiance or to set simulator irradiance levels in terms of a reference solar spectral irradiance distribution.

Short circuit current (Isc):

The output current of a photovoltaic device in the short-circuit condition at a particular temperature and irradiance.

Solar cell:

The basic photovoltaic device that generates electricity when exposed to sunlight.

Solar cell area:

The entire frontal area of the solar cell, including the cell grid (cm²).

Spectral response (absolute) (S abs):

The short circuit current density generated by unit irradiance at a particular wavelength (AW־¹), plotted as a function of wavelength.

Spectral response (relative) (S rel):

The spectral response normalised to unity at wavelength of maximum response.

Voltage temperature coefficient:

The change of the open circuit voltage of a PV device per degree Celsius change of cell temperature. This coefficient varies with irradiance and to a lesser extent with temperature.